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ABSTRACT

This paper uses a theoretical framework for concept mapping as an instance of a learning environment - the knowledge arena - and examines it against an existing framework for active learning called REAL (Rich Environment for Active Learning). The paper is intended to help in the understanding of environments for learning. Section 1 defines a knowledge arena as a virtual space where learners can operate on ideas, or concepts. This engagement involves a concept map. Section 2 describes concept maps and their use. Section 3 focuses on concept mapping and how it facilitates concept development and reflection. Section 4 examines concept mapping attributes. Section 5 defines learning environments and notes the attributes of REALs. Section 6 focuses on knowledge arenas and REALs, highlighting two consequences of what can be learned by using the knowledge arena as an example of a learning environment (the knowledge arena facilitates communication, and concept mapping influences the acquisition of cognitive skills in a knowledge arena). The paper concludes that concept mapping, construed as a knowledge arena, makes a useful contribution to understanding REALs and understanding learning. Similarly, REALs provide a useful framework for understanding concept mapping. (Contains 56 references.) (SM)

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The Knowledge Arena: a learning environment that underpins concept mapping.

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Abstract

This paper uses a theoretical framework for concept mapping as an instance of a learning environment - **The Knowledge Arena**, (McAleese, 1994, 1998a, 1998b) and examines it against an existing framework for active learning (Rich Environments for Active Learning (**REAL**), Grabinger, Dunlap & Duffield, (1998) The aim of the paper is to better understand environments for learning. Adjuncts to study and learning are becoming increasingly important in preparing learners for formal and informal education opportunities. The "concept map" or "mind map" (e.g. Novak & Gowin, 1984; Buzan, 1993) is a ubiquitous tool that has been used in computer-based applications (Fisher *et al*, 1990) and paper and pencil applications. While there is a significant literature on its use and methodology, there has been no coherent explanation of the concept map as an **interactive dynamic adjunct to learning**. The paper argues that there are both Strong and Weak comparisons between the elements of the Knowledge Arena framework and REALs.

The Theoretical Model – The Knowledge Arena

A knowledge arena (**KA**) is the name for a virtual space where learners can operate on ideas - that is concepts. In practice this engagement involves a **concept map**. A map being either a 2-D diagram or a computer screen (a virtual space ⁱⁱ 2-D/3-D; n-D) where learners can operate on ⁱⁱⁱ their understandings. Why? We propose that the **knowledge arena** is an extension of working memory. It is commonly accepted that working memory is limited and progressively declines over time and age (Daneman & Carpenter, 1980; Baddeley, 1992) A metaphor is helpful in making this clear. The **KA** is like a marquee - set up beside a house where one can have a party that would be too big for the house. It is therefore *like* an extension to working memory. If one extends the metaphor, the **KA** is where a complex gig-saw can be spread out - before finding a table that fits!! A **KA** model for concept mapping has been successfully developed from computer applications (McAleese, 1985) and learning and study skills (McAleese, 1992, 1994) While there is considerable literature on concept mapping (for example, Bogden, 1977; DeBono, 1993; Deikhoff, 1982; Fisher, 1990; Fisher, Faletti, Patterson, Thornton, Lipson, & Spring, 1990; Fisher & Kibby, 1996; Gaines & Shaw, 1994; Gold, 1984; Kommers, 1992; Novak, 1991a; 1991b, Reader & Hammond, 1993) - there is no coherent explanation of the process of mapping that addresses the conceptual steps involved. ^{iv} What is a "concept map"? An explanation and definition is necessary at this point.

The Concept Map

McAleese has provided a number definitions of concept maps in earlier papers. (McAleese, (1987;1990;1992;1994;1998a; 1998b). A concept map is defined here as "*a directed acyclic n-dimensional graph consisting of a set of m Concept Labels {C1 ... Cn} and a non-empty set of r Relationships or Arcs {R1... Rn}*"^{vi} The representation of an idea in a concept map does not determine its truth value as individuals may hold "non-truthful" understandings.^{vi} Therefore a concept maps in no way evaluates the status of the understandings held.^{vii} The representation of these sets is in the form of a diagram. Strictly the map is a graph - however hand drawn and computer generated maps are still "diagrams". Different representational forms are used to make diagrams of the graphs (Jonassen, et al 1998). The most popular - in terms of study aids - is the Mind Map (Buzan(1993). The term "concept map" is used here generically and includes, but is not limited to, *concept maps* (Novak, 1964, 1991a, 1991b; Novak & Gowin, 1991), *mind maps* (Buzan & Buzan, 1993), and *semantic networks* (Fisher, 1990; Fisher, Faletti, Patterson, Thornton, Lipson, & Spring, 1990; Fisher & Kibby, 1996; Fisher, Wandersee & Moody, In Press), as well as *clustering* (Rico, 1983; Ambron, 1988), *webbing* (Lovitt & Burk, 1988), and perhaps *concept circles* (Wandersee, 1987).

Kathleen Fisher has been prominent in developing an understanding of a form of concept mapping based on a computer application SemNet. Fisher - who refers to "Knowledge Mapping" has made significant contribution to the application of the mapping technique to domain of Biology. (see, for example, Fisher, et al 1999) The SemNet software (Fisher, 1990; Fisher et al., 1990; Fisher & Kibby, 1996; Fisher, et al, 1999) supports personal knowledge construction by permitting learners to construct efficiently semantic network images of their knowledge in the computer. It is designed primarily on the basis of Quillian's (1967; 1968; 1969) model for the way in which people store denotative factual knowledge in long term memory. The semantic networks produced by SemNet are typically larger than a concept map, and often contain hundreds of concepts. They also typically include much more detailed descriptions of each main idea than a Novak-type concept map does.

The usual approach is to create a network by adding "instances," which are **{concept}-{relation}-{concept}** links (see above). Learners typically begin with a concept that already exists in the network, and add links to each new concept. Since an instance represents the basic unit of meaning that captures the nature of the relation between two related concepts, this is an efficient approach to knowledge construction. With this approach, it is possible to build a network of ideas quickly – adding 20 to 80 concepts per hour (this is the range observed in novices to experts). The process - in cognitive terms - is sufficiently similar to

McAleese's position to allow the **Knowledge Arena** metaphor to be used here for the purpose of explicating learning environments.

Concept Mapping

Starting with a static description of what is a dynamic process, the following phases can be identified. Individuals tend to create nodes first; then make relationships; followed by labeling of relationships and typing of nodes. This model draws on the work of Sowa (1983) and Sweller & Chandler (1991).^{viii}

(a) The Concept Map - comprising *n* {Concept Labels} and *m* [Relationships/ Arcs] displayed on the computer monitor gives rise to a sensory image (*S*). The image is a representation of the Concept Map (*M*). The image is created through sensory input channels - e.g. the eyes and activates specialised areas of the visual cortex.

(b) An Associative Comparitor finds one or more Percepts (*P1 to Pn*) from a cognitive store that match some or all of *S*.

(c) An Assembler combines the retrieved Percepts to form a Working Model or Cognitive Graph that approximates to *S*. For each Percept in the Working Model - there is an isomorphic Concept Label *C1 to Cn*. The creation of the Working Model is a transient stage. The Cognitive Graph is the stored understanding of any one idea.

(d) If such a Working Model can be constructed using the Percepts, the Map (*M*) is explained by the Working Model and by definition makes sense to the individual. This state leaves the individual "happy" or "content" that they can make sense of the idea using the map *M*.

(e) If the Working Model is in any way deficient or can not adequately explain the Map (*M*), the individual either shifts their attention to an other area of the Map - and steps a to d re-occur, or the individual retrieves an existing Cognitive Model of one or more Concepts. These Models lead to the creation of a new Concept label or relationship through interaction with the computer application.

(f) New Concept labels or relationships are created. This step is in response to the ambiguity created when the Working Model is not adequate to explain the sensory image (*S*). This step creates new nodes and/ or relationships.

(g) If the working mental model matches and explains the concept map, then the map makes sense to the individual. If the map also seems complete, the individual feels "happy," "content," satisfied, with a sense of accomplishment.

(h) Sometimes, reflecting upon the sensory image of the concept map, an individual will see a deficiency in the organisation of ideas as they exist in both the map and in their cognitive model. This can occur because the concept map in the computer serves as a mirror of the mind. It holds the individual's thoughts in place, so that the individual's working memory is then free to reflect upon and evaluate those thoughts. In this case, editing is likely to occur both in the computer-based concept map *and* in the individual's working mental model.

Concept mapping, as an environment, contributes to both the development of REALs in their broad sense and in the development of knowledge structures, in its individual sense. Concept mapping is particularly strong in facilitating concept development and encouraging reflection. Perhaps Fisher's term "**Knowledge Mapping**" might be used better to describe the process?

Concept Mapping Attributes

Specifically, the attributes concept mapping includes:

- recall of specific concepts and concept labels,
- organization of concepts into categories,
- systematic construction of appropriate cognitive structures such as hierarchies and temporal flows,
- development of multiple cognitive pathways to concepts thereby increasing understanding and links among ideas,
- facile use of templates (arrays of link types characteristic of nodes representing "things," "processes," or "events"),
- revision and polishing of captured ideas,
- sharing among learners of alternative representations of a single topic and consideration of the strengths and weaknesses of each,
- acquisition of cognitive flexibility (Spiro, et al, 1991),
- knowledge accessibility for use in problem solving and other skilled performances.

Learning Environments

A **Learning Environment** – (LE) is a generic name for where learners learn. It can comprise computer - to deliver instruction; a curriculum system e.g. problem based learning/ a Gagne hierarchy etc.... The **LE** is also be a pedagogic statement of how learners go about learning. In that it will have implicit and explicit assumptions about (amongst other things): what learning is; what is to be learned; how it might be learned

The constructivist exposition that is used for a **LE** has been developed by Grabinger *et al* (e.g. Grabinger & Dunlap, 1995) This "model" of a learning environment is comparable to MacFarlane's Intensely Supportive Learning Environment (**ISLE**) – a UK perspective (MacFarlane, 1993)

Rich environments for active learning are comprehensive instructional systems comprised of a number of strategies and tactics. The purpose of **REALs** is to engage students in dynamic, authentic, generative learning activities. In these activities, students are given increased control and responsibility over the learning process while they learn both content and life-long learning skills including problem-solving, critical thinking, and collaboration. (Dunlap & Grabinger, 1992; Grabinger & Dunlap, 1996; Grabinger & Dunlap, 1994a; Grabinger & Dunlap, 1994b; Grabinger, Dunlap & Heath, 1993). REALs are based on a constructivist view of learning, which holds that knowledge is acquired through "a process of subjective construction on the part of the experiencing organism rather than a discovering of ontological reality" (von Glasersfeld, 1979, p. 109). This is then, by definition, a student-centered process. It is also a process of negotiation and conversation (Johnson, Johnson, & Smith, 1991; Pask, 1976), testing, and challenging (Bauersfeld, 1995; Cobb, 1994). This model of a learning environment compares to MacFarlane's Intensely Supportive Learning Environment (ISLE's) a UK perspective (MacFarlane, 1992).

Attributes of REALs

Specifically REALs:

- encourage the growth of student responsibility, initiative, decision making, and intentional learning;
- utilize dynamic, interdisciplinary, generative learning activities that promote high level thinking processes (i.e., analysis, synthesis, problem solving, experimentation, creativity, and examination of topics from multiple perspectives);
- enhance students' domain-specific and generic cognitive and metacognitive skills development (Schön, 1984) for meaningful learning;
- help students integrate new knowledge with old knowledge and thereby create rich and complex knowledge structures promoting understanding, pathways, and links among ideas;
- enhance the ability to organize concepts into categories and, thus, recall specific concepts and concept labels;
- promote study and investigation within authentic (i.e., realistic, meaningful, relevant, complex, and information-rich) contexts;
- cultivate an atmosphere of knowledge building learning communities that utilize collaborative learning among students and teachers (Collins, 1995);
and perhaps,

- help student move along the continuum from concrete to formal thinking.

Knowledge Arena and REALs

What can be learned by using the KA as an example of a learning environment?
Two main consequences emerge:

- The Knowledge Arena Facilitates Communication;
- Concept Mapping Influences the Acquisition of Cognitive Skills in a Knowledge Arena

a) The Knowledge Arena Facilitates Communication

Within many countries such as the UK, the USA, South Africa and India, coping with multiple languages is the norm. **Tools** to facilitate communication and learning across languages and in complex knowledge domains are very much needed, as is theory to guide their development. Steven Pinker in his best-selling book, "The Language Instinct," uses the term "mentalese" to describe how we think. There is strong evidence that the representations we use in thinking are largely **not** language based **or** language dependent. Rather, people think with mental imagery and skeletal representations of ideas similar to those proposed by Quillian thirty years ago and in some ways captured in concept mapping and semantic networking applications. (see Quillian, 1967, 1968, 1969) Further, linguists believe that people all over the world and in all walks of life use similar forms of "mentalese." That is, images and skeletal representations of ideas theoretically can tap into our thinking processes, allow us to represent what we are thinking in quick and easy fashion, and also can be readily translated into another language so as to allow us to share our ideas across the language barrier. Rapid translation is facilitated because concept maps and semantic networks use basic language elements only - noun concepts and phrases, simple verbs and verb phrases, and adjectives and adverbs. There are no complete sentences or complex linguistic structures to unpack.

In this paper we draw on theoretical and empirical bases for the use of bilingual Spanish/English representations to support biology learning. In addition to providing support for English as a Second Language (ESL) learning and for cross-language Spanish/English communication, we examine the extent to which mapping supports development of cognitive and metacognitive skills.

b) Concept Mapping Influences the Acquisition of Cognitive Skills in a Knowledge Arena

Among the skills influenced by mapping are; recall of specific concepts – concept labels; understanding and recall of **links** between ideas; establishing multiple pathways to concepts; organizing concepts into categories;

systematically constructing appropriate cognitive structures; learning to use templates (collections of link types characteristic of certain types of nodes such as "things" or "processes"); revision and polishing of captured ideas; sharing alternative representations of a single topic and considering the strengths and weaknesses of each; acquiring cognitive flexibility; making knowledge accessible for use in problem solving and other skilled performances.

We can compare Concept Mapping (as described as a **Knowledge Arena**) and **REALs**. There are a number of areas where Concept Mapping is particularly useful in implementing a **REAL**. The Table 1 below summarizes the various elements of the Knowledge Arena and compares it with attributes of the REAL.

Knowledge Arenas (c.f. McAleese, 1994)	REALs (c.f. Grabinger and Dunlap, 1996)	<u>Comparison</u> ^{ix}
1. A study aid that is governed by self-efficacy and self-regulatory procedures helping learners make sense of what has been learned and what is to be learned.	1. Intentional learning	Strong
2. Use of virtual and recursive computer modeling to promote the development of multiple perspectives and rich knowledge structures.	2. Multiple perspectives and dynamic generative learning	Strong
3. Computer modeling allows negotiation of understandings to resolve ambiguities and to reconcile and differentiate ideas.	3. Experimentation	Strong
4. In as much as the map is an <u>external representation</u> , it relates to what has to learned and the real world.	4. Authentic representation and task	Weak
5. Facilitates communication within the learner – reflection, self appraisal, efficacy, and regulation.	5. Metacognitive skills	Strong
6. Facilitates intra-learner communication and collaboration.	6. Collaborative skills	Weak or Strong^x

Table 1: A comparison of the Attributes of a "Knowledge Arena" and "Rich Environments for Active Learning"(REAL)

Conclusion and Implications

What initial conclusions can be drawn from this comparison? We conclude , from the summary above, that Concept Mapping - construed as a "**Knowledge Arena**" - makes a useful contribution to an understanding of REALs and in the understanding of learning. Similarly, **REALs** provide a useful framework for understanding concept mapping. To date, no single exposition has attempted to provide a micro-analysis of the cognitive processes at work while learners come to know. As a framework that supports educational development – the "learning environment" - **REAL** - is proving a rich and robust metaphor for developers, theorists and administrators. The technique of looking at the micro-level in concept mapping draws interesting parallels. While the **Knowledge Arena** is a useful way of thinking about concept mapping – **REALs** are not isomorphic with **Knowledge Arenas**.

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ⁱ These two citations represent two different traditions - the US tradition (Joe Novak) and a European tradition (Tony Buzan).

ⁱⁱ "Virtual Space" implies an arena where a learner can perform operations on computer generated entitles (text, lines, graphic items) - displayed on a screen or some virtual display device.

ⁱⁱⁱ "operate" and "operate on" are terms that suggest and describe learners actively and willingly representing manipulating and modifying signs for concepts. The process is active and involves cognitive engagement in the motor processes.

^{iv} A number of significant papers have appeared on concept mapping - cited in this paper above. However in most cases there is only passing reference of the "process of mapping" (see in addition, papers in the recent *Journal of Interactive Learning Research*, 1997)

^v This definition covers the genus of "concept maps" and includes species such as "mind maps" and "spray diagrams".

^{vi} By "truth" we mean an objective assessment of the accuracy or validity of any understanding held. For example, a learner might believe and represent the following understanding: "{Tides} are_caused_by ([the] Moon)". It is reasonable for a learner to believe that the rise and fall of tides is caused by the influence of The Moon. The "truth" of the understanding - to the learner - is not in question. The "accuracy" of the understanding to a wider and perhaps "objective" scientific community - is open to question as a literal explanation of why tides rise and fall. In that sense, and only in that sense, the assertion : "{Tides} are_caused_by ([the] Moon)" is [TRUE] for the particular learner in question.

^{vii} This distinction excludes formalisms such as

^{viii} NB: the "model suggested, covers both the McAleese **Knowledge Arena** and Fisher's Knowledge Mapping.

^{ix} This "comparison" is intended to allow a subjective comparison between the attributes of the "knowledge arena" and the "REAL". In making this comparison we use a simple ordinal scale: **Strong** and **Weak**. In making this comparison, the reader is asked to make his or her own judgement - based on the arguments above.

^x It depends on the method of map construction. If the maps are constructed collaboratively, then there is a Strong mapping - if they are constructed individually, then a Weak mapping.